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MANUFACTURE OF FRICTION PARTS  
BY USSR POWDER-METALLURGY METHODS

CORROSION-RESISTANT METAL-CERAMIC MATERIALS WITH IRON BASE -- Moscow, Vestnik Mashinostroyeniya, Mar 52

Many metal-ceramic [powder metallurgy] articles (filters made of bronze pellets, porous bearings, magnets, friction parts, contacts, and others) are being widely utilized in industry.

Corrosion-resistant metal-ceramic materials are of great interest in the production of various kinds of sealing parts, which are used, for example, in fittings, in aircraft engines, etc. However, these materials have not been studied, and practically no data on their properties and methods of production are to be found.

The writer has conducted research (with V. S. Rakovskiy, Candidate of Technical Sciences, as a consultant) investigating the properties and developing a method for the production of corrosion-resistant metal-ceramic materials.

The studies were conducted by using an iron powder (obtained by reducing drops with hydrogen) having a grain size from 30 to 120 microns, with most of the grains approximating the lower limit in size. Cylinders 15 millimeters in diameter and 40 millimeters high were made from the iron powder by pressing and were then subjected to sintering with concurrent chromizing. Three methods of chromizing were used: solid, solid in the presence of chromium chlorides, and gaseous.

Following chromizing, the structure of the specimens was studied; hardness and corrosion-resistance of the specimens were determined, as well as thickness of the chromium layer.

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Experimental samples of chromized seal rings were then made and subjected to technological tests after being set into fittings.

Solid chromizing was conducted in the following manner (Figure 1): Specimens made of the compressed iron powder were placed in a porcelain tube, and the tube was filled with crushed chromium; the tube was then placed in a furnace. One end of the tube was closed with a stopper, the other by means of a hydraulic seal. The process lasted for 4 hours at a temperature of 1,200 degrees centigrade.

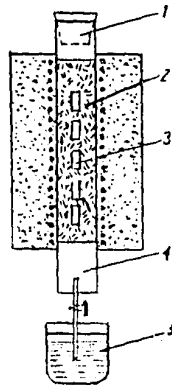


Figure 1. Unit for solid chromizing: (1) rubber stopper; (2) chromium; (3) specimens; (4) porcelain tube; (5) water.

Solid chromizing in the presence of chromium chlorides was effected in an analogous manner, the only difference being that the contents of the tube were impregnated with hydrogen chloride for 5 - 10 minutes before being placed in the furnace, after which both ends of the tube were sealed.

Gaseous chromizing was conducted in accordance with the conventional method in a hydrogen chloride medium.

The average thickness of the diffusion layer obtained by the different chromizing methods is characterized by the following figures:

<u>Methods</u>	<u>Millimeters</u>
In solid chromizing	1.0
In solid chromizing in the presence of chromium chlorides	1.9
In gaseous chromizing	3.5

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Figure 2 shows photographs of the specimens following chromizing.



Figure 2. Depth of chromium diffusion layers: (a) in solid chromizing; (b) in chromizing in the presence of chromium chlorides; (c) in gaseous chromizing. Etched with a 5-percent solution of  $\text{HNO}_3$ .

For further investigations, the method of solid chromizing in the presence of chromium chlorides was selected. The influence of the duration and temperature of the process, the grain size of the original powder, and the extent of sealing during compression on the thickness of the chromized layer and on the properties of the articles was determined. The results so obtained are shown in Figure 3, 4, and 5. As can be seen from these curves, the depth of the layer increases with increased duration of the chromizing process and with decreased compression pressure. The depth of the layer of some of the polished specimens was measured after etching in a 5-percent solution of  $\text{HNO}_3$ ; while the depth of the layer on other specimens was determined by their temper colors after they had been heated in a furnace for 15 minutes at 400 degrees centigrade.

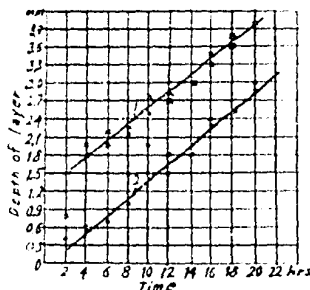


Figure 3. Effect of chromizing duration on the depth of the diffusion layer: (1) depth of the entire chromized layer; (2) depth of light (not etched) chromized layer. Temperature of impregnation, 1,150 degrees centigrade.

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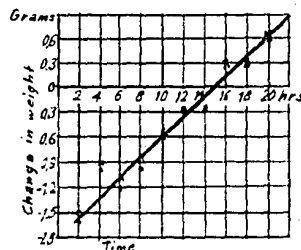
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Figure 4. Effect of chromizing duration on change in weight of the specimens: Temperature of impregnation, 1,150 degrees centigrade. • -- after etching, x -- after heating.

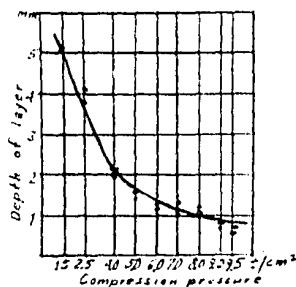


Figure 5. Effect of compression pressure on depth of diffusion layer. Temperature of impregnation, 1,150 degrees centigrade; duration of chromizing, 5 hours.

Porosity (characterized by change in weight of the specimen) at first increases sharply, owing to the burning out of the admixtures and reduction of iron oxides, and then decreases gradually as a result of diffusion of chromium into the compressed specimen.

Grain size of the powder has no substantial effect on the depth of the layer.

Subsequently, distribution of chromium according to the depth of the diffusion layer was investigated. The specimens were compressed under a pressure of 4 tons per square centimeter and were then chromized at different temperatures (for 5 and 3 hours). Then, chips of 0.5-millimeter thickness were cut in layers from the specimens, and the chromium content within each layer was determined. The results thus obtained are shown in Figure 6

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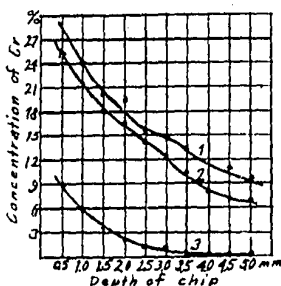
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Figure 6. Change of chromium concentration according to depth of diffusion layer: (1) time of chromizing, 5 hours; temperature, 1,200 degrees centigrade; (2) time of chromizing, 5 hours; temperature, 1,150 degrees centigrade; (3) time of chromizing, 3 hours; temperature, 1,050 degrees centigrade.

The nature of the curves is the same as in the case of diffusion-chromized steel, with the only difference that in the curve obtained for steel there is a point of more pronounced change in chromium concentration, corresponding to the limit of the  $\alpha$  —  $\gamma$  phases at the diffusion temperature.

Curves 1 and 2 show that the point corresponding to an abrupt change in chromium concentration, that is, the limit of corrosion resistance, is located at a depth of 3 millimeters. This depth permits almost any mechanical processing of the chromized metal-ceramic articles without danger of altering their corrosion properties, whereas chromized steel can be subjected to only light polishing.

Studies of the microstructure of the specimens have shown that the diffusion layer consists of an  $\alpha$  — solid solution of chromium in iron, containing at the surface 30 - 40 percent chromium. Under this layer is a transition zone with a 12 - 14 percent chromium content, corresponding to the  $\gamma$  — phase of the Fe -- Cr structural diagram; this zone is less susceptible to etching than the base metal (iron). Under this is the base ferrite. The characteristic features of chromized metal-ceramic materials are a less pronounced division between individual layers than in the case of ordinary chromized steel, and a change of porosity in cross section. Relatively, the least porosity is found in the diffusion layer, while the highest is present within the transition zone.

Figure 7 shows the microstructure of one of the specimens.

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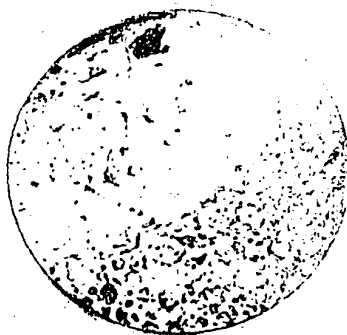
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Figure 7. Diffusion layer and transition zone: Magnified 50 times; time of chromizing, 6 hours; temperature, 1,100 degrees centigrade; water quenching from 1,100 degrees centigrade.

Thereafter, corrosion tests were carried out, the specimens tested being chromized throughout. The specimens were subjected to the action of a 10-percent solution of nitric acid at room temperature and at boiling point for a period of 72 hours. Results of the tests are shown in the following table.

Test Conditions in 10-Percent Solution of $\text{HNO}_3$	Relative Loss of Weight (g/59m)	
	Metal-Ceramic Specimens	Stainless Steel Specimens
Room temperature (25 degrees centigrade)	0.08	0.62
Boiling point	0.16	1.2

It must be borne in mind that the actual corrosion-resistance of chromized metal-ceramic specimens is considerably higher than that characterized by data shown in the above table, because in the latter case, only the outside surface was considered (without taking into account the surface of pores).

On testing porous specimens not chromized throughout, intensive corrosion occurs, owing to penetration of the acid solution into the pores and pitting of the iron component.

With respect to atmospheric action, the specimens fully chromized, as well as those partially so, were found to be very stable. For example, specimens stored for a 5-year period in a room where chrome heat treatment was carried out showed no signs of corrosion.

To ascertain the possibility of producing nonporous metal-ceramic articles, the specimens, after being chromized, were impregnated with molten copper (Figure 8) or with Bakelite resin (Figure 9). In both instances, the pores were completely filled.

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Figure 8. Microstructure of specimen impregnated with copper. Magnified 100 times.



Figure 9. Microstructure of specimen impregnated with Bakelite resin. Magnified 100 times.

The materials obtained were tested for tensile strength. Test data are shown in following table.

<u>Characteristics</u>	<u>Specimens Impreg- nated With Copper</u>	<u>Specimens not Impregnated</u>
$\sigma_b$ [Tensile strength] (in kilograms per square millimeter)	40 -- 50	Up to 10
$\delta$ [Specific Elongation] (in percent)	0.5 -- 7.0	---

For determination of technological characteristics, an experimental batch of seal rings for a valve of a steam fitting (with the through hole 50 millimeters in diameter) was produced. After chromizing, the seal rings were impregnated with Bakelite resin (impregnation with copper required mechanical processing). The rings inserted into the valve groove were rolled in (Figure 10), while those in the valve body were rolled out (Figure 11).

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Figure 10. Fitting the ring into the valve: (a) before rolling in; (b) after rolling in.

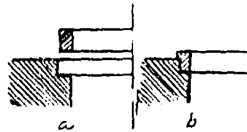


Figure 11. Fitting the ring into the valve body: (a) before rolling out; (b) after rolling out.

The technological tests conducted at the plant have shown the feasibility of producing seal fittings from iron powder with subsequent chemical heat treatment with chromium. However, industrial production of the seal fittings must be preceded by research work on the problem of imparting greater plastic properties to the rings; this can be attained by selection of a suitable impregnating compound and by heat treatment.

Figure 12 shows the seal rings after chromizing and polishing.



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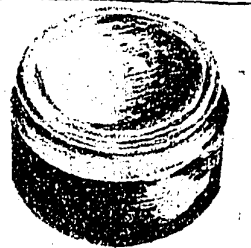
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Figure 13 shows a valve with a rolled-in ring.



The method developed for production of corrosion-resistant metal-ceramic articles does not require the designing of new equipment; it is based on equipment now being used in powder metallurgy. This method can be used to protect metal-ceramic articles (made of iron powder) from atmospheric corrosion and also, in chemical machine building, to produce filters which operate in corrosive media and at elevated temperatures.

BIMETALLIC METAL-CERAMIC (POWDER METALLURGY) PARTS -- Moscow, Vestnik Mashinostroyeniya, Mar 52

Utilization of methods of powder metallurgy for the production of metal-ceramic (powder metallurgy) bimetallic antifriction parts affords a number of advantages. These methods make it possible to produce antifriction parts with a layer of porous metal. Because of the pores (from 10 to 40 percent), this layer wears in well and will retain a reserve of lubricant.

Powder-metallurgy methods lend themselves well to the production of anti-friction compositions (iron and graphite, bronze and graphite, etc.) which cannot be manufactured by other methods and of bimetallic parts with high friction properties (as a result of adding such components as silicon oxide, asbestos, iron, cinders, etc., to the composition). Moreover, the need for machining parts is obviated, and a large saving of nonferrous metal is attained.

Antifriction and friction bimetallic parts are produced by powder-metallurgy methods according to one of the following plans:

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Preparation of Mixture (raw materials:  
powders of iron, copper, tin, lead,  
graphite, silicon oxide, asbestos)

Pressing of briquette	Pressing of briquette	Sintering of sprinkled layer on steel base	Pressing of iron layer
Sintering	Sintering under pres- sure, together with steel base	Pressing	Sintering
Fastening to steel base	Processing (grinding)	Final sintering	Pressing of antifriction layer
Plan II			
Processing (grinding)		Processing (bending, machining)	Sintering
Plan I		Plan III	
			Sizing
			Plan IV

These plans differ mainly in the methods of bonding the metal-ceramic layer to the steel base. For production of bimetallic metal-ceramic parts, plans III and IV are of most significance.

Research conducted at the Orgavtoprom Institute (All-Union State Institute of Automobile Technology) has made it possible to develop the technology of manufacturing bimetallic metal-ceramic parts (thin-wall linings and bimetallic bushings) by the two plans mentioned above.

The process of manufacturing thin-wall linings for bearings consists of the following operations:

#### 1. Preparation of the Mixture

The mixture is made up of powders of copper (70.5 percent), lead oxide (29.0 percent), and graphite (0.5 percent). After blending in a mixer for 5-6 hours, a homogeneous mixture is obtained.

#### 2. Application of a Layer of Powder on the Steel Base and Primary Sintering

The powder mixture is sprinkled on the previously tin-plated surface of steel blanks or strip. Sintering takes place at a temperature of 740-760 degrees centigrade for 45-60 minutes.

#### 3. Compression of the Sintered Layer

Compression is accomplished at a pressure of from 1.5 to 3.5 tons per square centimeter (depending on the required porosity of the antifriction layer) on presses (if blanks are desired) or by means of rolling (if a strip is desired).

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4. Secondary Sintering

The procedure is the same as in primary sintering.

5. Impregnation With Oil

Porosity of the metal-ceramic layer of a fully sintered blank varies within the range of 5-15 percent. To improve antifriction properties, the layer is impregnated with oil in an oil bath at 110-120 degrees centigrade for 1-1.5 hours.

6. Final Processing

The blanks for the lining are subjected to bending and machining. Bending is done in dies; machining of the metal-ceramic layer consists of boring or broaching. The layer cannot be ground, because in so doing, abrasive particles would enter the outer pores of the metal-ceramic material.

When powder-metallurgy methods are used in the production of thin-wall bimetallic linings, only one-fifth to one-fourth as much nonferrous metal is required, and the labor consumption in manufacture is decreased two or three times.

The second plan for the production of bimetallic parts is applicable to bearing bushings only.

In the production of bimetallic metal-ceramic bushings, it must be remembered that the joint must be strong enough to withstand pressure fitting of the bushing; and the torque, caused by shaft friction, must not produce stresses exceeding the elastic limit on the contact layer.

Calculations, as well as research and experimental work that have been conducted, have substantiated the feasibility of manufacturing bimetallic bushings from powder with strongly bonded layers. (Shear stresses in pressing out the inner layer amount to 4-5 kilograms per square millimeter.)

A strong joint is assured by creating stresses during pressing and by roughness of the contact layer. In regard to the requirement that the layers be sintered at different temperatures (720 degrees centigrade for the bronze layer and 1,100 degrees centigrade for the iron layer), the process of manufacturing a bimetallic bushing is subdivided into two operations; one for producing the outer (iron) bushing and the other for making the inner antifriction bronze layer.

The technology developed for manufacturing such bushings includes the following operations:

1. Sifting of the Initial Powders

Sifting must ensure the retention of definite percentages of different fractions in the powder. The recommended composition of the powders in regard to grain size is shown in the following table.

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<u>Grain Size</u> (in meshes)	<u>Fraction Contents of Powders</u>		
	(in %)		
	<u>Iron</u>	<u>Copper</u>	<u>Tin</u>
+100	Up to 30	--	--
-100 - +150	30 - 35	Up to 10	--
-150 - +200	18 - 25	20 - 25	Up to 5
-200 - +325	10 - 15	20 - 25	20 - 35
-325	10 - 20	30 - 45	60 - 80

## 2. Preparation of the Bronze-Graphite Mixture

For the production of a bronze layer, a mixture of powders is used which has the following composition: 87 percent copper, 10 percent tin, and 3 percent graphite powder. Mixing is done in ordinary mixers for 4-5 hours.

## 3. Measuring Out the Iron Powder and Pressing of the Iron Bushing

The iron powder can be measured out either by volume or by weight.

## 4. Sintering of the Iron Bushings

This operation is performed in furnaces filled with a protective atmosphere (nitrogen-hydrogen mixture, hydrogen, or generator gas) at a temperature of 1,050-1,100 degrees centigrade. The sintering process lasts for 1.5 hours. It is recommended that sintering be done in continuous-operation furnaces equipped with a condenser.

## 5. Sizing of Iron Bushings

The sintered bushings are sized in special dies to give them their final dimensions.

## 6. Press Fitting the Inner Bronze Layer into the Iron Bushing

The iron bushing is placed in a die and the compressed bronze layer and iron bushing are press fitted together. The bronze layer is pressed at a pressure of 1.3-1.5 tons per square centimeter.

## 7. Sintering of the Inner Layer

The pressed bushing, consisting of two layers, is sintered at a temperature of 720-740 degrees centigrade for 1-1.5 hours. The process takes place either in a protective atmosphere or in boxes containing activated carbon.

## 8. Impregnation With Oil

The sintered bimetallic bushing is impregnated with oil. Impregnation conditions are as follows: temperature of oil bath, 110-120 degrees centigrade; duration, one hour; cooled in the oil.

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9. Sizing of Bimetallic Bushings

The finished bushings are sized to give them the required dimensions and surface finish.

Sizing of bushings with respect to their inner and outside diameters is done in a sizing die.

It must be pointed out that bimetallic bushings can be produced not only with an internal but also with an external antifriction layer by powder-metallurgy methods.

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